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Camboulives et al.

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[45] **Sept. 24, 1974**

[54] **VARIABLE-GEOMETRY NOZZLE FOR A JET ENGINE**

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[21] Appl. No.: **371,659**

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June 19, 1972 France 72.22052

[52] **U.S. Cl.** **239/265.39,** 239/265.37

[51] **Int. Cl.** **B64c 15/04**

[58] **Field of Search**..... 239/265.33, 265.37, 265.39, 239/265.41; 60/229

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Primary Examiner—M. Henson Wood, Jr.
Assistant Examiner—Michael Y. Mar

[57] **ABSTRACT**

A variable-geometry nozzle for a jet engine is of the type which comprises a fixed structure, flaps adjustable in position with respect to the fixed structure, and control means for adjusting the position of the flaps. A plurality of swivelling frames are arranged around the circumference of the nozzle and are separately hinged to the fixed structure for pivotal adjustment about axes perpendicular to the longitudinal direction of the nozzle. The control means comprise jacks operable to pivot the frames about their respective axes, and the adjustable flaps are connected to the frames. The flaps comprise, in resect of each frame, two flaps each of which is hinged to the corresponding frame for positional angular adjustment with reference to that frame about an axis which has a component perpendicular to the pivotal axis of the frame concerned.

12 Claims, 16 Drawing Figures

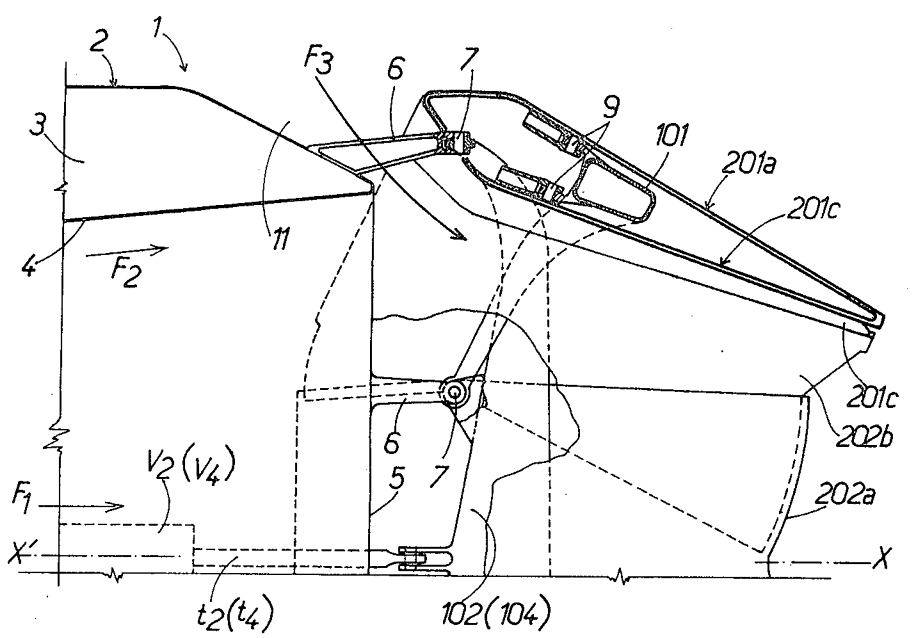
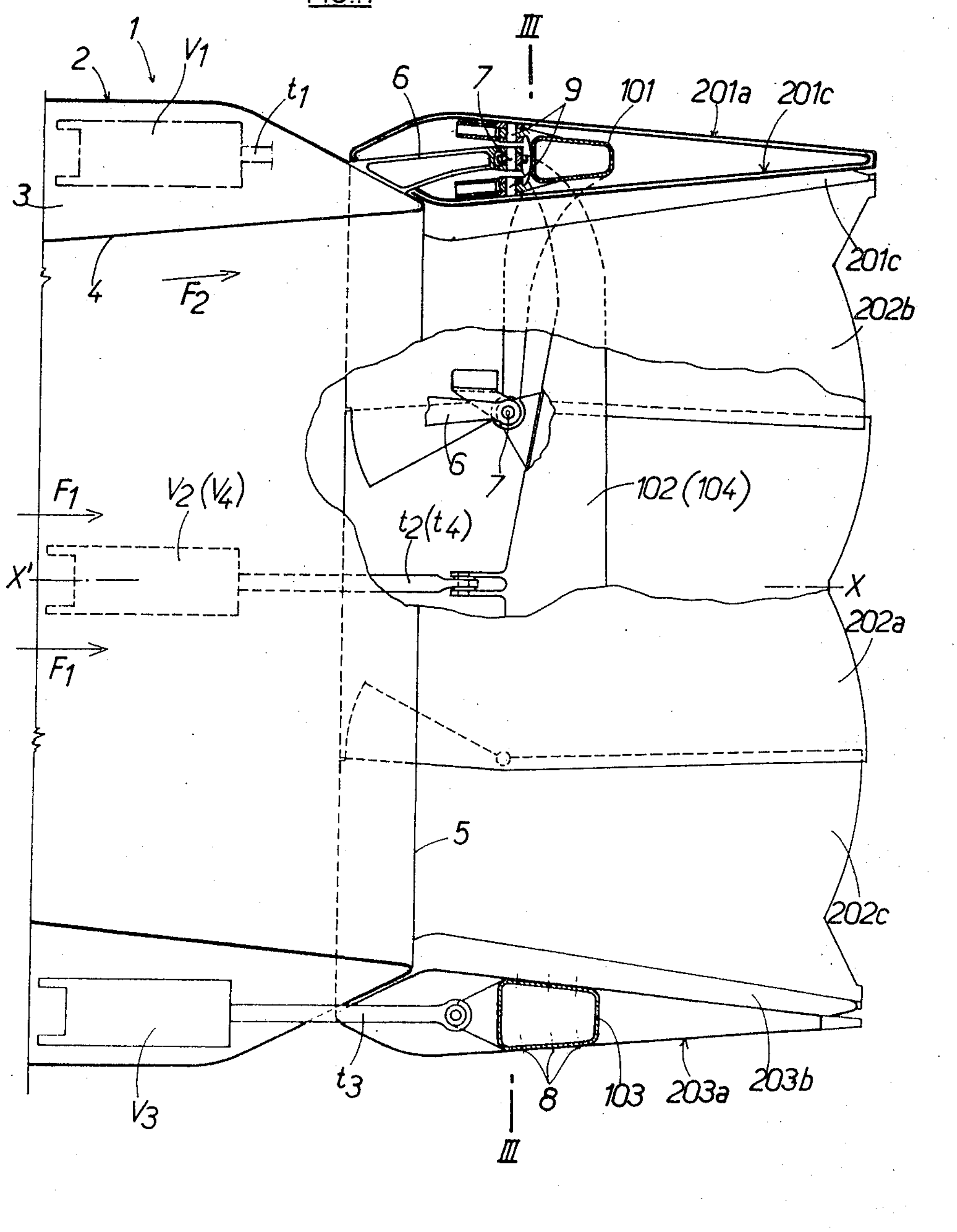


FIG. 1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1
2
V1
t1
3
4
F2
6
7
9
101
201a
201c
201c
202b
6
7
102 (104)
F1
V2 (V4)
t2 (t4)
X'
X
F1
202a
5
202c
V3
t3
8
103
203a
203b
III

FIG.: 2

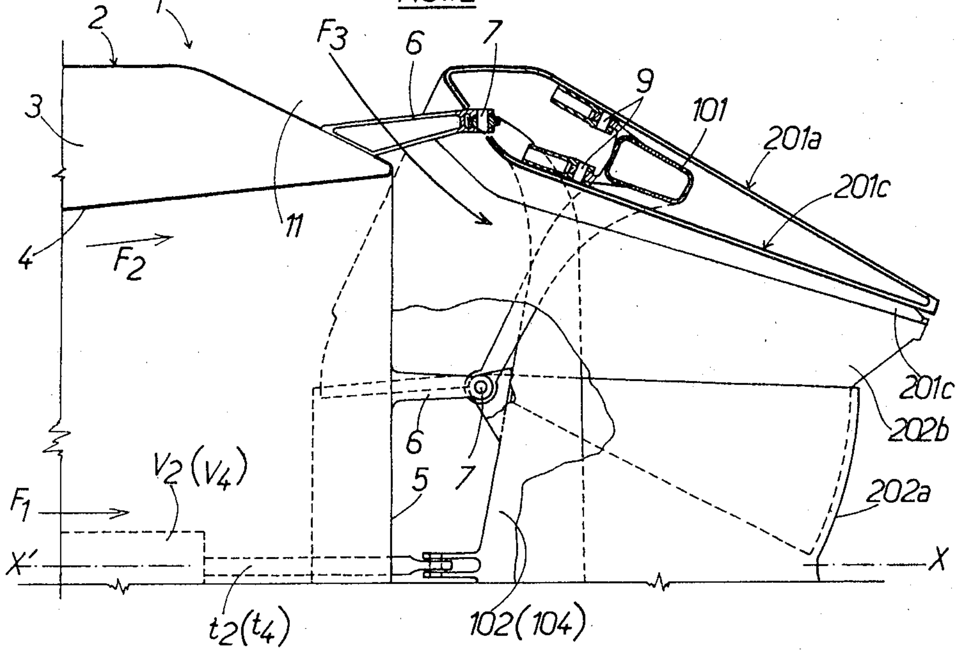
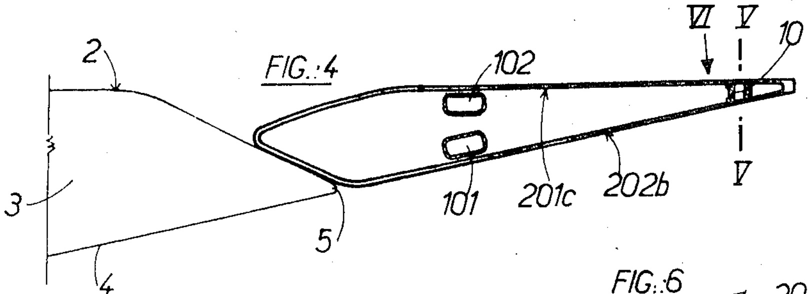


FIG.: 4



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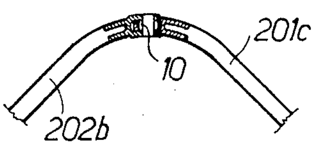

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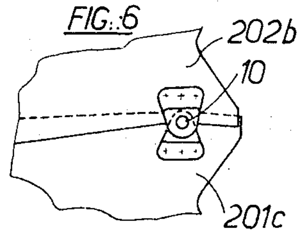

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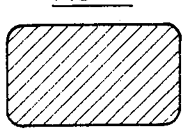

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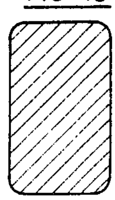

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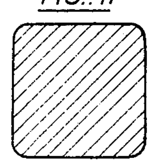

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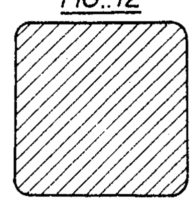

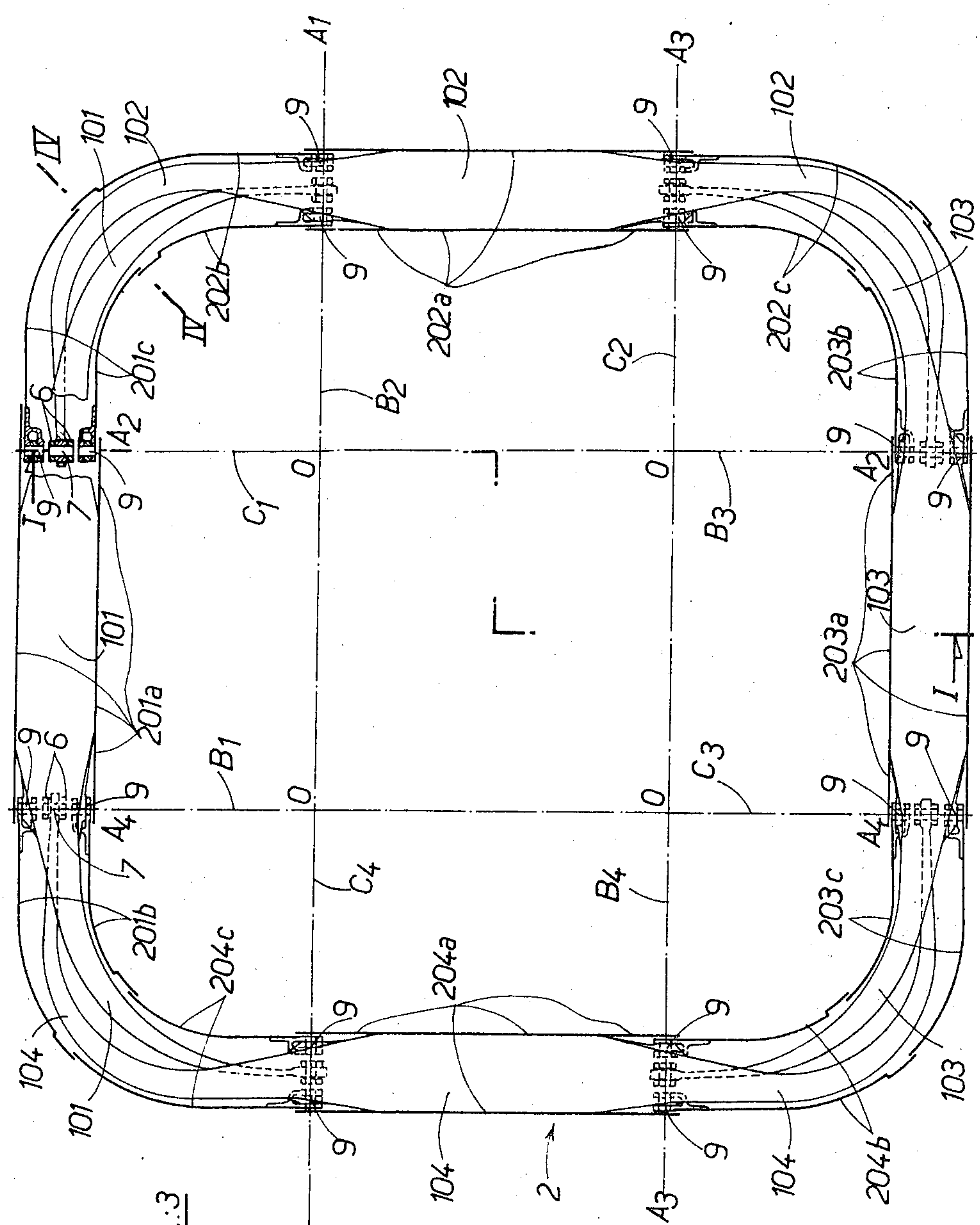
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A2
A3
A4
B1
B2
B3
B4
C1
C2
C3
C4
O
I
IV
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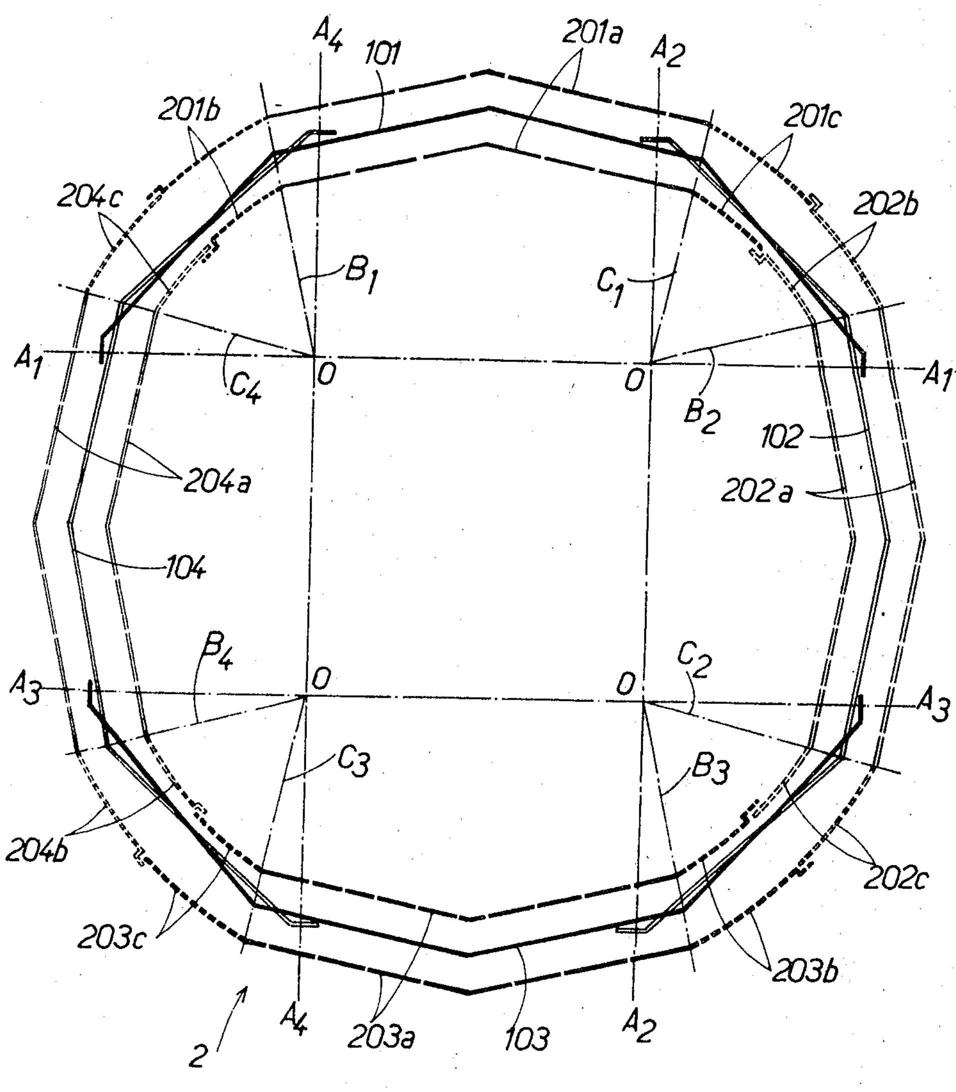
7
9
101
102
103
104
201a
201b
201c
202a
202b
202c
203a
203b
203c
204a
204b
204c
2

FIG. 3

FIG.: 7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A1
O
O
A1
C4
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102
204a
202 a
104
B4
C2
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O
O
A3
C3
B3
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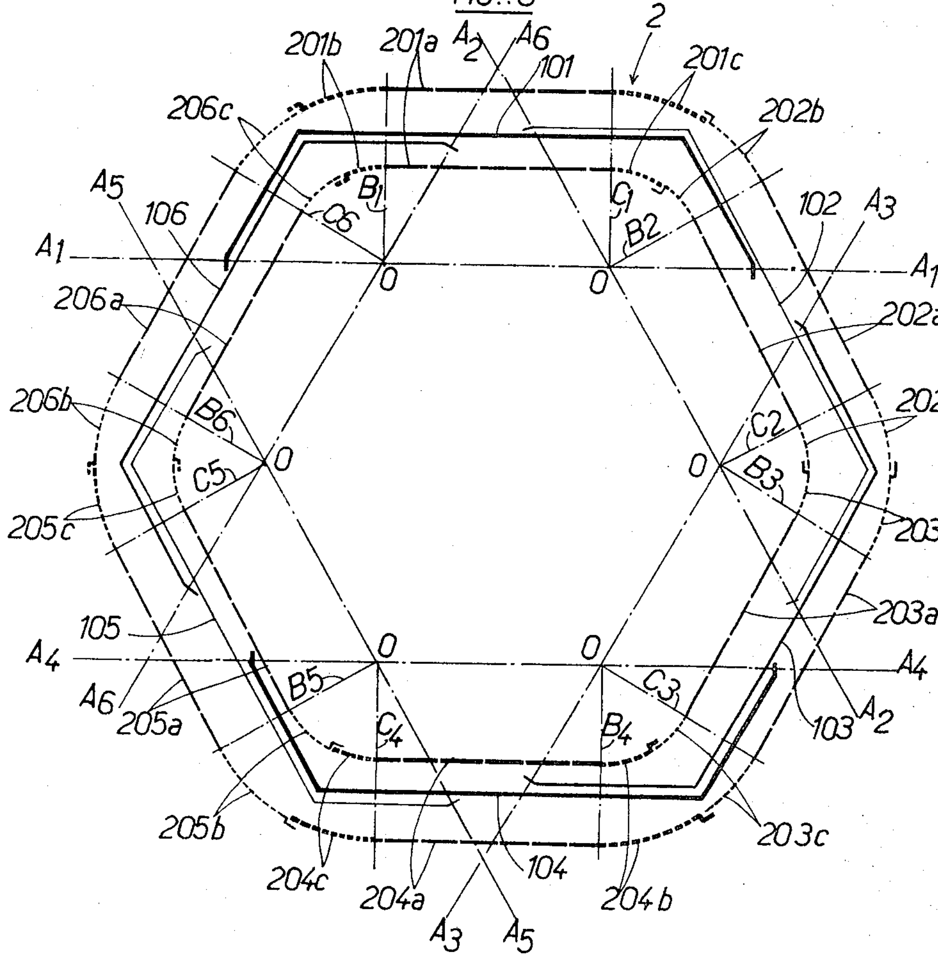
202c
203c
203b
A4
203a
103
A2
2

FIG.: 8


2
201b
201a
A2
A6
101
201c
206c
202b
A5
B1
C1
106
C6
B2
102
A3
A1
O
O
A1
206a
202a
B6
206b
C2
202c
O
O
C5
B3
205c
203b
203a
105
O
O
A4
A4
B5
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B4
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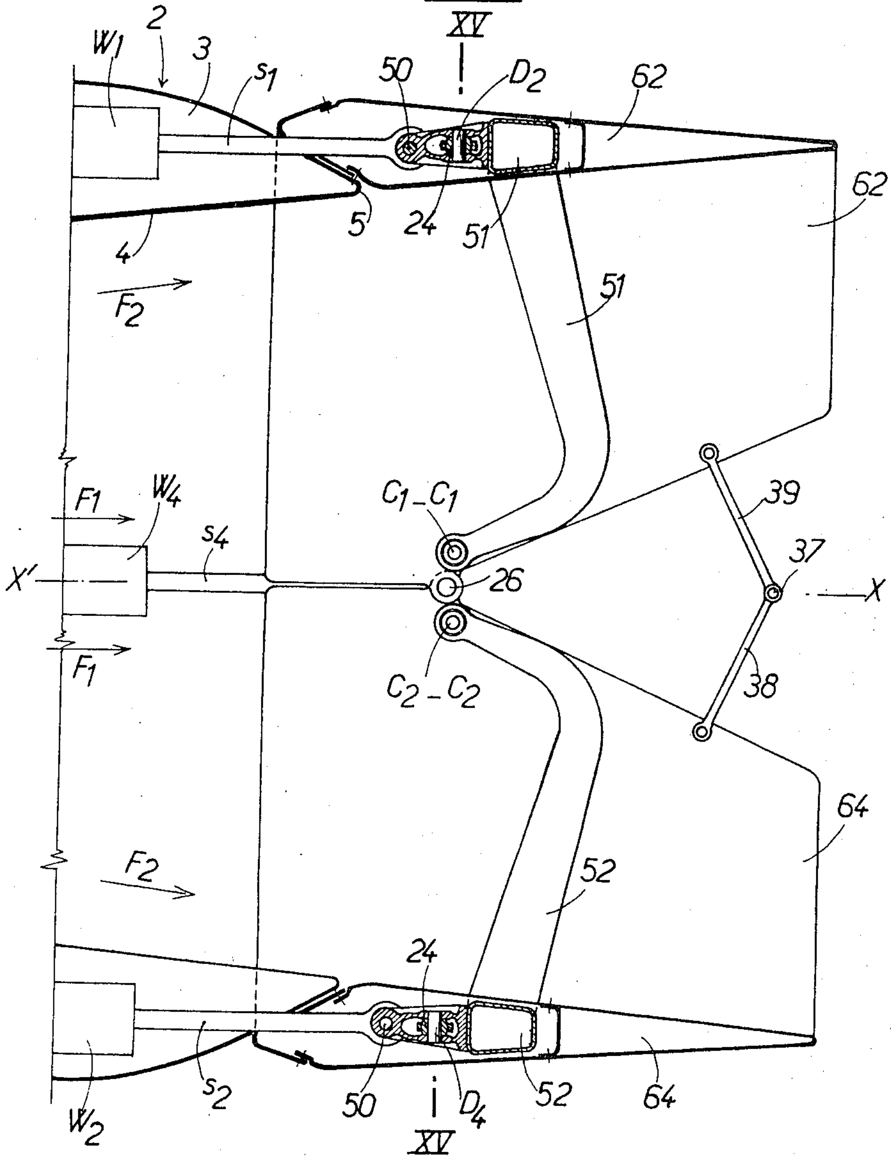
104
204c
204a
204b
A3
A5

FIG.: 13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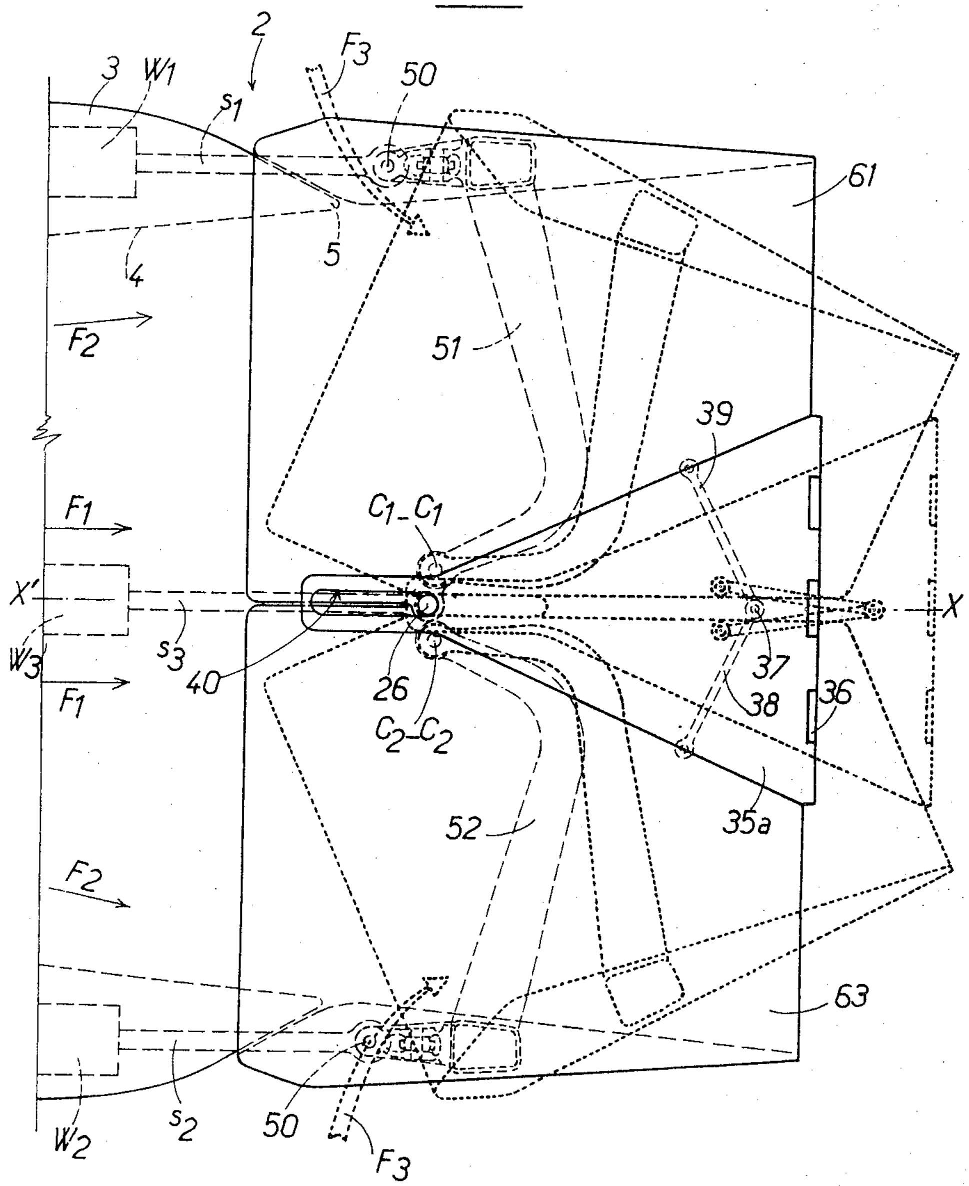
3
s1
50
D2
62
62
5
24
51
4
F2
51
C1-C1
39
F1
W4
s4
37
X'
26
X
F1
C2-C2
38
64
F2
52
24
s2
50
D4
52
64
W2
XV

FIG.:14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W1
s1
F3
50
61
5
4
F2
51
39
C1_C1
F1
X'
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s3
40
26
F1
C2_C2
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X
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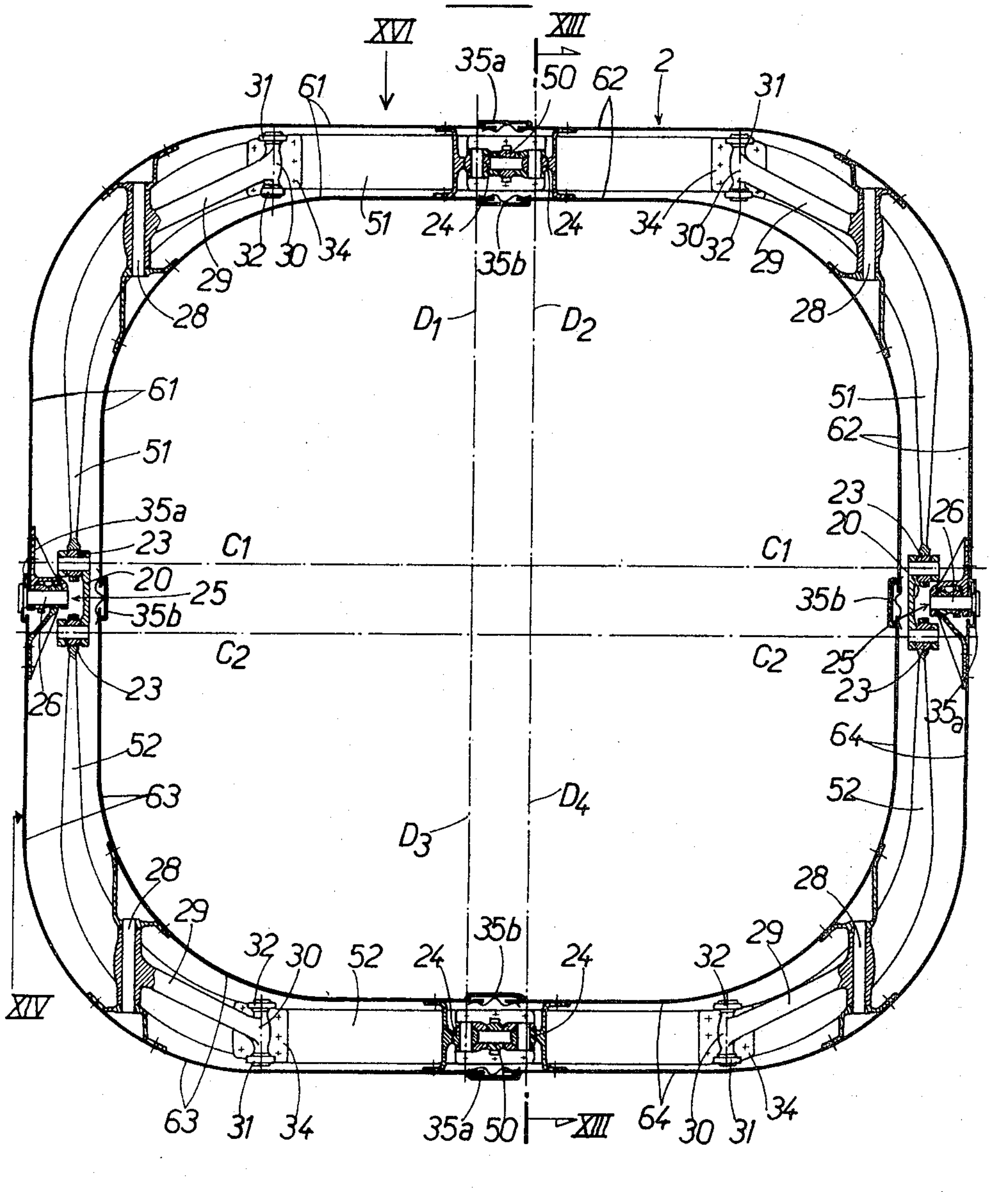
35a
F2
63
W2
s2
50
F3

FIG.:15


XVI
XIII
35a
50
62
2
31
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51
24
35b
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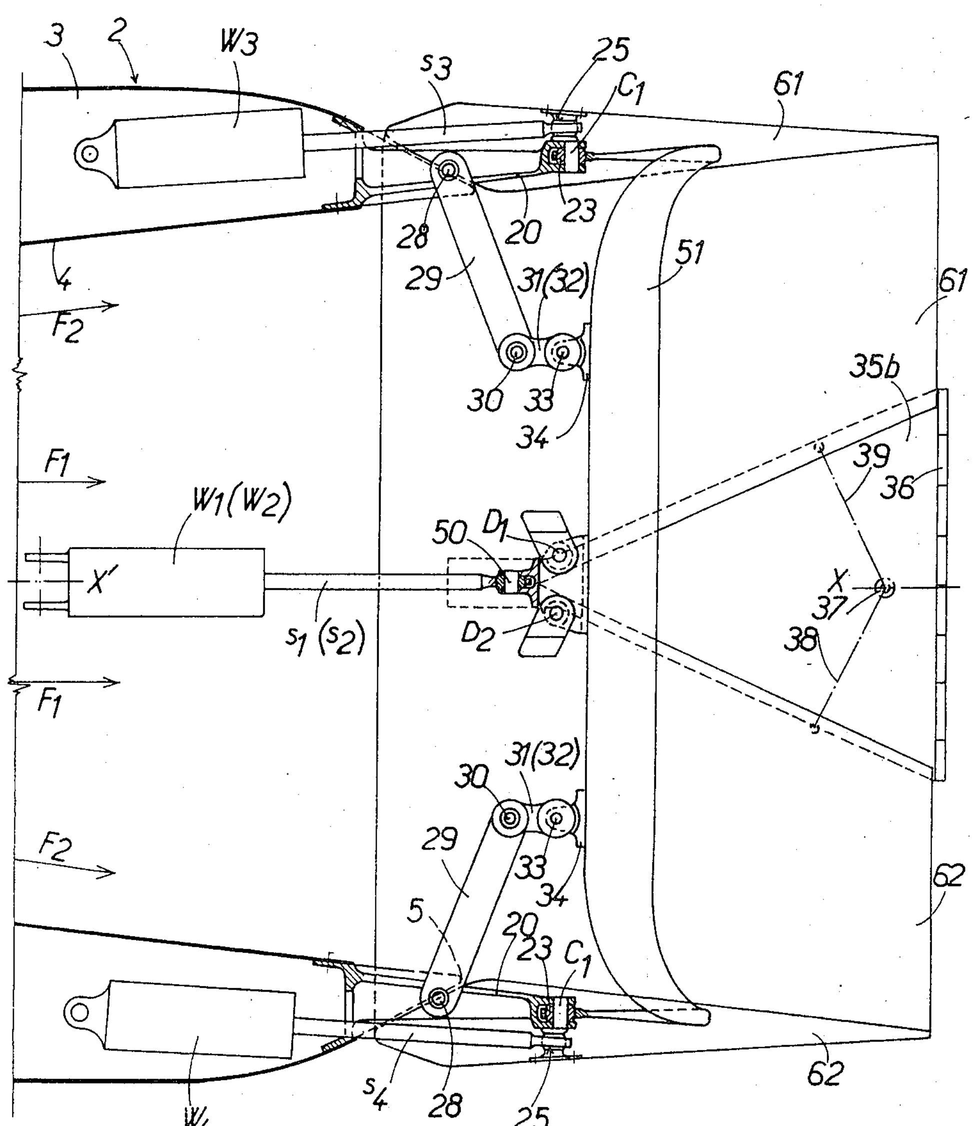
C1
C2
20
23
25
26
64
52
63
D3
D4
XIV

FIG.:16


3
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C1
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31(32)
51
61
F2
30
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35b
F1
39
36
W1(W2)
D1
50
X
X'
37
D2
S1 (S2)
38
F1
31(32)
30
F2
29
33
34
62
5
20
23
C1
S4
28
25
62
W4

VARIABLE-GEOMETRY NOZZLE FOR A JET ENGINE

This invention relates to a variable-geometry nozzle for a jet engine, the nozzle being of the type which comprises a fixed structure, flaps adjustable in position with reference to the fixed structure, and control means for adjusting the position of the flaps. As is commonly known, such nozzles are used to achieve the optimum adaptation of a jet engine to a wide range of flight conditions.

One mandatory condition which a commercial jet-driven aircraft must observe is that its jet engines emit a minimum of noise at low altitudes, more especially in the course of take-off and landing, and likewise in the fly-over phase (a climb at full thrust followed by a reduction of thrust as soon as the aircraft has reached a safe height).

Various devices have already been proposed which achieve a reduction in the noise emitted by the jet-flow leaving a jet engine. These noise-reducing devices generally comprise special accessory parts which project into the said jet-flow, the contour of which they so modify as to increase the surface where this jet-flow mingles with the surrounding air.

These known devices, however, have the drawback that they bring about quite considerable losses in thrust, and it is therefore essential that they should be capable of retraction from the jet-flow as soon as their use is no longer necessary, a point which complicates the design and control of the nozzle.

In a general way, the present invention aims at providing a propulsion nozzle able, without the assistance of any accessory part, greatly to reduce the noise made by the jet-flow as it leaves a jet engine during take-off (or landing) phases and during fly-over phases, while still subsequently providing optimum thrust in all the other flight phases of the aircraft.

The invention also has the aim of providing an exhaust nozzle able selectively to reduce the noise emitted by the jet-flow in two given directions, namely in the horizontal plane of symmetry of the nozzle, during the take-off (or landing) phase, and in the vertical plane of symmetry of the nozzle during the fly-over phase.

According to the invention a variable-geometry nozzle, of the type which comprises a fixed structure, flaps adjustable in position with reference to the fixed structure, and control means for adjusting the position of the said flaps is notable in that it comprises, arranged on its periphery, at least two swivelling frames, each of which frames is hinged to said fixed structure in such a way as to be able to undergo angular adjustment in its position with reference to the fixed structure through rotation about an axis perpendicular to the longitudinal direction of the nozzle; in that said adjustable flaps are connected to swivelling frames and comprise, in respect of each frame, two actuated flaps each of which is itself hinged to the said frame in such a way as to be able to undergo angular adjustment in position with reference to said frame through rotation about an axis which possesses a component perpendicular to the axis of rotation of the frame; and in that the control means for the flaps comprise motor means, such as jacks, to cause each of said frames to turn with reference to the said fixed structure.

According to a preferred embodiment of the invention, the swivelling frames are distributed around the periphery of the nozzle and are at least equal to four in number. They are preferably even in number and are arranged so that the axes of rotation of two oppositely situated frames, on either side respectively of a longitudinal plane of symmetry of the nozzle, are parallel to each other.

According to one arrangement applicable in this case, the adjustable flaps comprise, in respect of each frame, three actuated flaps, namely a middle flap rigidly attached to the said frame and two side flaps which enframe the middle flap and are hinged to the frame, the arrangement being such that each side flap hinged to a frame is peripherally adjacent to a side flap hinged to the neighbouring frame. Peripherally adjacent side flaps are preferably inter-linked in their downstream portion by hinge means.

According to another embodiment of the invention, the swivelling frames are two only in number and are arranged oppositely, on either side respectively of a longitudinal plane of symmetry of the nozzle, in such a way that their respective axes of rotation are parallel to each other. In this case, the control means for the flaps also comprise motor means to cause each of the flaps to turn with reference to the frame to which it is hinged.

According to an arrangement applicable in this case, two actuated flaps which are peripherally consecutive and are hinged to one or other of the two swivelling frames, respectively, are inter-linked by hinge means in such a way that one can turn in relation to the other about an axis which is virtually parallel to the respective axes of rotation of the said frames. The motor means to cause each of the flaps to turn with reference to the frame to which it is hinged, then comprise a motor device, such as a jack, which is associated with each group of two consecutive actuated flaps hinged to one or other of the said swivelling frames respectively, and which has one part integral with the said hinge means.

The invention applies more particularly to the case in which the fixed nozzle structure comprises a duct traversed by a gaseous flow, the said duct being terminated by a downstream edge. According to one arrangement of the invention applicable in this case, the adjustable flaps may, under the action of the aforementioned control means, take up an open position in which their upstream edge comes virtually into contact with the downstream edge of the said duct, the flaps then forming a downstream extension of this duct, and a closed position in which their upstream edge is at a distance from the downstream edge of the duct, in such a way as to define a passage through which a flow of atmospheric air (sometimes designated by the expression "tertiary air flow") is able to penetrate the said gaseous efflux.

As will be seen hereinafter, a nozzle thus equipped makes it possible to achieve a selective noise reduction which is at its maximum in the horizontal plane of the nozzle during the take-off and landing phases, and also at its maximum in the vertical plane of symmetry of the said nozzle during the fly-over phase of the aircraft. In addition to its noise-reducing effect, this nozzle renders possible a selective supply of tertiary air, either mainly through or entirely through the upper and lower planes of the nozzle during take-off or landing, either mainly through or entirely through the lateral planes of the nozzle in the fly-over phase, or past the entire periphery of the nozzle when at subsonic cruising speed.

The following description, with reference to the accompanying drawings and given by way of non-limitative example, brings out how the invention may be put into effect, In the drawings:

FIG. **1** is a longitudinal sectional view, taken along the line I—I in FIG. **3**, of a variable-geometry nozzle according to a first embodiment of the invention, the nozzle being shown in the completely open position;

FIG. **2** is a view similar to that in FIG. **1**, but here the nozzle is in partly closed position;

FIG. **3** is a cross-sectional view, taken along the line III—III in FIG. **1**, of the nozzle illustrated in FIG. **1**;

FIG. **4** is a part sectional view, taken along the line IV—IV in FIG. **3**, of the nozzle shown in FIG. **3**;

FIG. **5** is a part sectional view, taken along the line V—V in FIG. **4**, of the nozzle shown in FIG. **4**;

FIG. **6** is a fractional view, looking in the direction of the arrow VI in FIG. **4**, of the nozzle shown in FIG. **4**;

FIG. **7** is a diagrammatic view similar to FIG. **3** and showing a modification of the first embodiment of the invention;

FIG. **8** is a diagrammatic view similar to FIG. **3** and showing a second modification of the first embodiment of the invention;

FIGS. **9, 10, 11** and **12** provide diagrammatic illustrations in cross-section of the various shapes which may be given to the exhaust section area of an improved nozzle in accordance with the invention;

FIG. **13** is a view in longitudinal section, taken along the line XIII—XIII in FIG. **15**, of a variable geometry nozzle in accordance with a second embodiment of the invention, the nozzle being shown in a completely open position and the inner wall of the nozzle being assumed to be transparent;

FIG. **14** is a side elevation view, looking in the direction of the arrow XIV in FIG. **15**, of the same nozzle;

FIG. **15** is a cross-sectional view, taken along the line XV—XV in FIG. **13**, of the nozzle illustrated in FIG. **13**, and

FIG. **16** is a plan view, looking in the direction of the arrow XVI in FIG. **15**, of the nozzle shown in FIG. **15**, here the upper wall of the said nozzle being assumed to be transparent.

FIGS. **1** to **6** refer to a first embodiment of the invention and in these figures the general reference numeral **1** denotes an exhaust assembly for a jet propulsion engine. This exhaust assembly is of the type known as "composite" or "ejector," comprising at the least a primary jet-pipe (not shown) traversed by a primary gaseous flow F_1 and terminating in a secondary nozzle **2**. This secondary nozzle will in the following part of the description be designated simply by the term "nozzle."

The nozzle **2** comprises, more especially, a fixed structure **3** which bounds a duct **4** traversed by a flow of secondary air F_2, the duct **4** terminating a downstream edge **5**. The fixed structure **3** is extended in the downstream direction by means of brackets **6** spaced apart peripherally.

On the periphery of the nozzle **2** there are arranged four swivelling frames **101, 102, 103, 104**, each one constituted by a hoop each end of which is hinged to a corresponding bracket **6** by a bell joint **7**. As is shown in FIG. **3**, each of the frames is thus hinged to the fixed structure **3** and may be adjusted angularly in position with reference to the fixed structure by rotation about an axis perpendicular to the longitudinal direction X'-X of the nozzle. The axes of rotation of the four frames **101, 102, 103, 104** are respectively denoted by A_1-A_1, A_2-A_2, A_3-A_3, A_4-A_4, and it will be seen that the axes of rotation (such as A_1-A_1 and A_3-A_3) of the two frames (such as **101** and **103**) which are oppositely situated on either side respectively of a longitudinal plane of symmetry of the nozzle are parallel to each other, and that two non-parallel axes, such as A_1-A_1 and A_4-A_4, meet at a point O.

With each of the swivelling frames **101, 102, 103, 104** there is associated motor means, such as a control jack V_1, V_2, V_3 or V_4, which has a rod t_1, t_2, t_3 or t_4 the end of which is hinged to the corresponding frame. It is therefore sufficient, to make a frame, such as **101**, turn about its axis A_1-A_1, to actuate the corresponding jack V_1. It is advantageous — though this is not mandatory — that the jacks V_1 and V_3 should be mutually synchronized, and similarly the jacks V_2 and V_4.

To each swivelling frame, such as **101**, there are connected three actuated flaps, namely a middle flap **201***a* and two side flaps **201***b*, **201***c*, the latter two enframing the middle flap. The middle flap **201***a* is rigidly fixed to the frame **101**, for example by bolt means, by riveting or by welding, as indicated by the reference numeral **8** in FIG. **1** in respect of the frame **103**.

Each of the side flaps **201***b*, **201***c* is hinged to the frame **101** by means of a pin **9** so as to be capable of angular positional adjustment with reference to the frame by rotation about an xis B_1 (C_1) which has one component perpendicular to the axis of rotation A_1-A_1 of the frame. In the example shown in FIG. **3**, the axes B_1 and C_1 are perpendicular to the axis A_1-A_1, but this arrangement is not mandatory, as will be seen hereinafter.

In a similar manner, the reference numerals **202***a*, **203***a* and **204***a* have been used to denote the middle flaps rigidly fixed to the frames **102, 103** and **104** respectively, and the reference numbers **202***b* (**202***c*), **203***b* (**203***c*) and **204***b* (**204***c*) to denote the side flaps hinged to the frames so as to be able to turn about axes B_2 (C_2), B_3 (C_3) and B_4 (C_4) respectively.

As shown in FIG. **3**, each side flap (such as **201***b*) hinged to an swivelling frame (such as **101**) is peripherally adjacent to a side flap (such as **204***c*) hinged to a neighbouring frame (such as **104**). It will also be observed that the axes B_1 and C_3 have the same geometrical support, as do the axes C_1 and B_3, B_2 and C_4, and C_2 and B_4. It will finally be noted that two axes (such as B_1 and C_4) associated respectively with two side flaps (such as **201***b* and **204***c*) which are peripherally adjacent meet at the point O situated at the point of convergence of the axes of rotation (such as A_1-A_1 and A_4-A_4) of the frames (such as **101** and **104**) to which the flaps are hinged.

As is shown in FIGS. **4** to **6**, two peripherally adjacent side flaps (such as **201***c*, **202***b*) are joined together, at their downstream part, by a swivel-type hinge **10**.

Fluid tightness between peripherally consecutive flaps is ensured by the mutual overlapping of these flaps. If, for example, the overlapping of two flaps, such as **201***a* and **201***b*, is taken into consideration (see FIG. **3**), it will be observed that the female portion of one of the flaps (in this instance flap **201***a*) must have a geometrical form which is that of the volume produced by the rotation about the axis B_1 of the section of the flap **201***b* through a plane (in this instance, the plane of FIG. 3) containing the said axis (a field of application of Guldin's theorem).

An examination will now be made of the operation of the nozzle **2** just described, while also referring to FIGS. **9** to **12.**

On take-off of the aircraft, the jacks V_1 and V_3 are actuated so as to cause the swivelling frames **101** and **103** to turn about their respective axes A_1-A_1 and A_3-A_3. As a consequence of this movement, the middle flaps **201***a* and **203***a*, supported by the said frame respectively, turn through the same angle and move to close the nozzle **2** partially along its two horizontal sides. According to whether the jacks V_2 and V_4 are either not actuated or actuated in the direction of opening, the swivelling frames **102** and **104**, as well as the middle flaps **202***a* and **204***a*, either remain immobile or are set to an angular open position determined by the optimum nozzle cross-section requirements.

As to the side flaps hinged to the four swivelling frames **101, 102, 103** and **104,** they turn with reference to the frames about their respective axes so as to maintain the continuity of the angular areas of the nozzle. In this connection, it is pointed out that in the course of this manoeuvre relative movement between the peripherally adjacent flaps occurs.

The nozzle **2** thus assumes the configuration shown in FIGS. **2** and **9,** with an oblong or flattened exhaust crosssection (See FIG. **9**) the long side of which is virtually parallel to the horizontal plane of symmetry of the nozzle. The jet-flow leaving the nozzle **2** is therefore mechanically "pinched" in a corresponding manner, and it has been established that such a pinching effect is accompanied by a modification to the spatial distribution of the noise energy emitted by the jet-flow of such a kind that, in the horizontal plane of symmetry of the nozzle, the more pronounced the pinching effect on the jet, the greater the noise reduction in the noise pattern. Thus, in particular, disturbance at ground-level owing to the noise made by the jet-flow at take-off is decreased.

It will be further noted that, in this configuration, the upstream edge of the middle flaps **201***a* and **203***a* is at such a distance from the downstream edge **5** of the duct **4** as to define passages **11** through which a flow F_3 of atmospheric air, called "tertiary air," is able to penetrate through the upper and lower planes of the nozzles into the flow of secondary air F_2 so as to mingle with the said flow and favourably modify its pressure level. This air also, as is already known, plays a useful part in the process of reducing the noise produced by the jet.

During the fly-over phase, the jacks V_2 and V_4 are actuated so as to cause the swivelling frames **102** and **104** to turn about their respective axes A_2-A_2 and A_4-A_4. As a consequence of this movement, the middle flaps **202***a* and **204***a* supported by these swivelling frames respectively, turn through the same angle and move to close the nozzle **2** partially along its two vertical sides. According to whether the jacks V_1 and V_3 are either not actuated or actuated in the direction of opening, swivelling frames **101** and **103,** as well as the middle flaps **201***a* and **203***a*, either remain immobile or are set to an angular open position determined by the optimum nozzle cross-section requirements.

The nozzle **2** thus assumes the configuration shown in FIG. **10,** with an oblong or flattened exhaust cross-section the long side of which is virtually parallel to the vertical plane of symmetry of the nozzle. The jet-flow leaving the nozzle **2** is therefore mechanically pinched in a corresponding manner, so that now a noise-reduction in the noise pattern is achieved in the vertical plane of symmetry of the nozzle. Thus, in particular, disturbance at ground-level owing to the noise made by the jet during fly-over is decreased. It will also be noted that, in this configuration, a flow of tertiary air is able to penetrate into the flow F_2 of secondary air through passages (similar to the passages **11**) formed through the side planes of the nozzle between the downstream edge **5** of the divergent duct **4** and the upstream edge of the middle flaps **202***a* and **204***a*.

In subsonic flight, the four jacks V_1, V_2, V_3, V_4 are actuated simultaneously so as simultaneously to alter the position of the four middle flaps **201***a*, **202***a*, **203***a*, **204***a*. The nozzle **2** then assumes the configuration shown in FIG. **11,** with a virtually square exhaust cross-section, and a supply of tertiary air around its whole periphery. Thus external and internal drag effects along the nozzle are reduced. By way of modification, the four jacks could be uncoupled from the frames they control so as to allow the flaps to shift freely about and to assume a position corresponding to the balance of internal and external pressures on either side of the flaps. It will also be noted that it would be possible to control the jacks in a differential manner so as to obtain a directional effect.

When flying in the supersonic cruise mode, the four jacks V_1, V_2, V_3, V_4 are actuated in such a way that the four middle flaps **201***a*, **202***a*, **203***a*, **204***a* are completely open. The nozzle **2** then assumes the configuration shown in FIGS. **1** and **12,** with an exhaust cross-section which is homothetic to the one shown in FIG. **11.** The flaps then occupy a position in which their upstream edge virtually comes into contact with the downstream edge **5** of the duct **4,** the flaps thus forming a downstream extension of the duct, being either aligned with the duct or otherwise. As the passages **11** are then blocked, the nozzle is no longer supplied with tertiary air.

It has been indicated hereinbefore that it was not mandatory for two converging axes, such as B_1 and C_4, to be perpendicular to each other.

FIG. **7** is a simplified diagrammatic view similar to FIG. **3** and specifically showing an arrangement in which the above-mentioned converging axes form between them an angle other than of 90°. In this figure, for denoting similar parts (the swivelling frames, middle flaps, hinged side flaps, axes of rotation of the frames and flaps) use has again been made of the same reference numerals as in FIG. **3.** As in the case of FIG. **3,** the axes of rotation of two consecutive swivelling frames (for instance, the axes of rotation A_1-A_1 and A_4-A_4 of the frames **101** and **104**) and the axes of rotation of two adjacent side flaps supported by the said frames respectively (in the present case, the axes of rotation B_1 and C_4 of the side flaps **201***b* and **204***c*) converge at the same point O.

When FIG. **7** is examined, the special shape (an inverted V) given to the middle flaps **201***a*, **202***a*, **203***a*, **204***a* will also be noted. A nozzle fitted out thus will therefore in cross-section have a polygonal form with a large number of sides and one approaching the conventional circular form. The junction of the nozzle with an upstream fairing arrangement having a circular cross-section, or with the remainder of the jet engine, can therefore be easily effected.

Up to now it has been assumed that the swivelling frames **101, 102, 103, 104** were four in number, distributed virtually around a square. But this arrangement is not limitative. Thus it would be possible to conceive other arrangements comprising, for example, six or eight swivelling frames distributed virtually in accordance with a hexagon or an octogon.

FIG. **8** is specifically an illustration of an arrangement comprising six swivelling frames **101, 102, 103, 104, 105, 106**, these being able to turn about axes A_1-A_1, A_2-A_2, . . . A_6-A_6, respectively. Each of these frames has connected to it, as described hereinbefore, three flaps, namely a middle flap **201***a* (**202***a* . . . **206***a*) which is fixed with reference to the said frame, and two side flaps **201***b* (**202***b* . . . **206***b*) and **201***c* (**202***c* . . . **206***c*) hinged to the said frame. The respective axes of rotation of these side flaps have been denoted by the references B_1, B_2, . . . B_6, and C_1, C_2, . . . C_6. Here too it will be noted that, as in the case of FIGS. **3** and **7**, the axes of rotation of two consecutive swivelling frames (for example, the axes of rotation A_1-A_1 and A_6-A_6 of the frames **101** and **106**) and the axes of rotation of two adjacent side flaps supported by the said frames respectively (in the present case, the axes of rotation B_1 and C_6 of the side flaps **201***b* and **206***c*) converge at the same point O.

FIGS. **13** and **14** relate to a second embodiment of the invention. In these figures, as hereinbefore the reference numeral **2** denotes a secondary nozzle with an axis X'-X and comprising a fixed structure **3** which bounds a duct **4** traversed by a flow of secondary air F_2, the duct **4** terminating in a downstream edge **5.** The flow F_2 surrounds in an already known manner a primary gaseous flow F_1 emitted by a primary nozzle (not shown here). The fixed structure **3** is extended downstream by two diametrically opposite brackets **20.**

On the periphery of the nozzle there are oppositely arranged, on either side respectively of a longitudinal plane of symmetry of the nozzle, two swivelling frames **51, 52**, each of them constituted by a hoop each end of which is hinged to a bracket **20** by means of a ball joint **23.** As is shown in FIG. **14**, each of the two frames **51, 52** is thus hinged to the fixed structure **3** and may be adjusted angularly in its position with reference to the said fixed structure by rotation about an axis C_1-C_1 (C_2-C_2) perpendicular to the longitudinal direction X'-X of the nozzle. The axes C_1-C_1 and C_2-C_2 are parallel to each other.

With each of the two swivelling frames **51, 52** there is associated motor means, such as a control jack W_1 (W_2) which as a rod s_1 (s_2) the end of which is hinged at **50** to the corresponding frame. It is therefore sufficient, to make a frame **51** (**52**) turn about its axis C_1-C_1 (C_2-C_2), to actuate the corresponding jack W_1 (W_2).

To each of the two frames **51, 52** there are connected two actuated flaps **61, 62** (**63, 64**), each one of which is attached to the corresponding frame with the aid of hinge means **24** (preferably of the type involving a ball joint so as to be capable of angular adjustment in its position with reference to the frame by rotation about an axis D_1 (D_2, D_3, D_4) perpendicular to the axis of rotation C_1-C_1 (C_2-C_2) of the said fitting. The axes D_1 and D_3 have the same geometrical support, as do the axes D_2 and D_4.

The peripherally consecutive flaps **61** and **63** (**62** and **64**) which are hinged to the swivelling frames **51** and **52** respectively are inter-linked by means of a ball joint **25** which comprises a pin **26** that is virtually parallel to the axes of rotation C_1-C_1 and C_2-C_2 of the frames **51** and **52.** The flaps **61** and **63** (**62** and **64**) are therefore able to turn in relation to each other about the pin **26.** The pins **26** relating to the flaps **61** and **63** on the one hand, and to the flaps **62** and **64** on the other, have the same geometrical support.

With each group of two consecutive actuated flaps **61–63** (or **62–64**) which are hinged to one or other of the two swivelling frames **51** and **52** respectively there is associated motor means, such as a jack W_3 (W_4) which has a rod s_3 (s_4) attached to the ball joint **25** of the said group of flaps. Thus, when, for example, the jack W_3 is actuated, the two flaps **61** and **63** turn simultaneously, each with reference to the frame **51** (**52**) to which it is hinged, moving about axes D_1 and D_3 respectively. Likewise, when the jack W_4 is actuated, the two flaps **62** and **64** turn simultaneously about axes D_2 and D_4 respectively.

It is advantageous — though this is not mandatory — that the jacks W_1 and W_2 should be mutually synchronized, and similarly the jacks W_3 and W_4.

Each of the flaps **61, 62, 63, 64** is pivotally attached by a hinge pin **28** to one of the ends of an arm **29.** The other end of this arm is pivotally attached by a hinge pin **30** to two parallel link-rods **31, 32.** The latter are themselves pivotally attached about a pin **33** to a yoke **34** integral with the swivelling frame **51** (involving the flaps **61** and **62**) or with the swivelling frame **52** (involving the flaps **63** and **64**). The hinge pins **28, 30** and **33** are perpendicular to the axes of rotation C_1-C_1 and C_2-C_2 of the swivelling frames **51** and **52.** This arrangement relieves the hinge means **24** by facilitating the guidance of the flaps and resisting the moments which are due to the pressure of gases against the flaps.

Fluid tightness between successive controlled flaps is ensured by four slaved flaps each one of which is composed of an outer plate **35***a* and an inner plate **35***b*, these plates being inter-connected by hinge means at their downstream edge **36.** Each slaved flap **35***a*, **35***b* is fitted at its downstream part with pivot means **37** to which two link rods **38, 39** are each pivotally attached by one of their ends. These link rods are pivotally attached at their other ends to two adjacent actuated flaps, respectively. Each slaved flap therefore undergoes displacement downstream at the time of the rotating movement of the two actuated flaps which enframe it (see FIG. 14).

With reference more especially to the two slaved flaps arranged between the two actuated flaps **61** and **63** (or **62** and **64**) that both pivot about a hinge pin **26**, it will be noted that each of them includes, in its upstream part, a slot **40** (see FIG. 14) made in the plate **35***a* and through which the pin **26** passes. As will be readily understood, this arrangement facilitates the centering of these two slaved flaps.

The operation of the nozzle **2** just described will now be considered, with due reference to FIGS. **9** to **12**, as in the preceding case.

On take-off of the aircraft, the rods of the jacks W_1 and W_2 move out, so causing the two swivelling frames

51 and 52 to turn about their respective axes C_1-C_1 and C_2-C_2. The rods of the jacks W_3 and W_4 retract, so that the pins 26 with which they are integral are placed in a position which is determined by the optimum-section conditions for the nozzle. As a consequence of the movement of the jacks W_1 and W_2, the four flaps **61, 62, 63, 64** undergo displacement along with the frames **51** and **52,** turning about the pins **26,** which are parallel to the axes C_1-C_1 and C_2-C_2.

The nozzle **2** thus shifts from the configuration shown in full lines to the one indicated by broken lines in FIG. **14,** with an exhaust cross-section which is oblong or flattened (see FIG. **9**), its long side being virtually parallel to the horizontal plane of symmetry of the nozzle. The jet-flow leaving the nozzle is therefore mechanically "pinched" in a corresponding manner, this achieving a reduction in the noise pattern in the horizontal plane of symmetry of the nozzle.

In this configuration, the upstream edge of the flaps is at such a distance from the downstream edge of the duct **4** as to define passages through which a flow of "tertiary" air F_3 is able to penetrate through the upper and lower planes of the nozzle into the flow of secondary air F_2, so mixing with the latter flow and favourably modifying its pressure level.

In the fly-over phase, the rods of the jacks W_3 and W_4 move out. The rods of the jacks W_1 and W_2 retract, so that the swivelling frames **51** and **52** are placed in a position determined by the optimum nozzle-section requirement. As a consequence of the movement of the jacks W_3 and W_4, the four flaps **61, 62, 63, 64** undergo displacement with reference to the frames **51** and **52,** turning about axes D_1, D_2, D_3, D_4 which are perpendicular to the axes of rotation C_1-C_1 and C_2-C_2 of the said frames.

The nozzle **2** thus assumes the configuration shown in FIG. **10,** with an oblong or flattened exhaust cross-section area the long side of which is virtually parallel to the vertical plane of symmetry of the nozzle. The jet-flow leaving the nozzle is therefore mechanically "pinched" in a corresponding manner, this now achieving a reduction in the noise pattern in the vertical plane of symmetry of the nozzle. In this configuration, a flow of tertiary air is able to penetrate into the flow of secondary air F_2 by way of passages formed along the side planes of the nozzle, between the downstream edge **5** of the duct **4** and the upstream edge of the flaps.

In subsonic flight, the four jacks W_1, W_2, W_3 and W_4 are actuated simultaneously in the same direction. The nozzle **2** then assumes the configuration shown in FIG. **11,** with a virtually square exhaust cross-section and a supply of tertiary air around its entire periphery.

As in the case of the first embodiment, the four jacks could be uncoupled so as to allow the flaps to shift about freely and to assume a position which corresponds to the balance of the internal and external pressures on either side of the said flaps. It would also be possible to control these jacks in a differential manner to obtain a directional effect.

When flying in the supersonic cruise mode, the rods of the four jacks W_1, W_2, W_3 and W_4 are completely retracted. The nozzle **2** then assumes the configuration shown in FIG. **12,** with an exhaust cross-section which is similar in shape to that shown in FIG. **11.** The four flaps **61, 62, 63, 64** then occupy a position in which they form a downstream extension of the duct **4,** and are aligned with the said duct or otherwise. In this configuration, the nozzle **2** is no longer supplied with tertiary air.

As will be seen, the nozzle according to the invention achieves a noise-reducing effect, when such is required, without it, however, being necessary to have recourse to special accessory parts: in fact, the very same flaps which simultaneously act to adjust the cross-section of the nozzle with a view to producing optimum thrust in all the flight phases of the aircraft are employed to give the nozzle a configuration which is favourable to the selective reduction of the noise from the jet in selected directions.

It is self-evident that the embodiments described are merely examples and that it would be possible to modify them, more especially by replacing them by technical means which are equivalent, without however departing from the scope of the invention.

We claim:

1. A variable-geometry nozzle for a jet engine, comprising a fixed structure, at least two swivelling frames arranged at the periphery of the nozzle and each of which is hinged to said fixed structure for positional angular adjustment with reference to the fixed structure by rotation about an axis perpendicular to the longitudinal direction of the nozzle, adjustable flaps connected to said swivelling frames and comprising, in respect of each frame, two actuated flaps each of which is itself hinged to the frame for positional angular adjustment with reference to the frame by rotation about an axis which possesses a component perpendicular to the axis of rotation of the frame, and control means for adjusting the position of the flaps and which comprise motor means operable to turn each of the frames relatively to the said fixed structure.

2. A nozzle according to claim **1,** wherein said swivelling frames are distributed around the periphery of the nozzle and are at least four in number.

3. A nozzle according to claim **2,** wherein said frames are even in number and are arranged so that the axes of rotation of two oppositely situated frames, on either side respectively of a longitudinal plane of symmetry of the nozzle, are parallel to each other.

4. A nozzle according to claim **2,** wherein said adjustable flaps comprise, in respect of each swivelling frame, three actuated flaps, namely a middle flap rigidly attached to the frame and two side flaps which enframe the middle flap and are hinged to the frame, and each side flap hinged to a frame is peripherally adjacent to a side flap hinged to the immediately adjacent frame.

5. A nozzle according to claim **4,** wherein said middle flap possesses, in section in a plane perpendicular to the longitudinal direction of the nozzle, the shape of an inverted V.

6. A nozzle according to claim **2,** wherein the axes of rotation of two peripherally consecutive swivelling frames and the axes of rotation of two peripherally adjacent flaps supported by these frames respectively intersect at one and the same point.

7. A nozzle according to claim **2,** wherein two peripherally adjacent flaps hinged respectively to two neighbouring frames are inter-linked at their downstream part by hinge means.

8. A nozzle according to claim **1,** wherein said swivelling frames are two only in number and are arranged oppositely, on either side of a longitudinal plane of symmetry of the nozzle respectively, in such a way that their respective axes of rotation are parallel to each other, and the control means for the flaps also comprise motor means operative to turn each of the flaps relatively to the frame to which it is hinged.

9. A nozzle according to claim **8,** wherein two peripherally consecutive actuated flaps hinged to one or other of the said swivelling frames, respectively, are interlinked by hinge means in such a way that one can turn in relation to the other about an axis which is virtually parallel to the respective axes of rotation of the frames.

10. A nozzle according to claim **9,** wherein the motor means operative to turn each of the flaps relatively to the frame to which it is hinged comprise a motor device which is associated with each group of two consecutive actuated flaps hinged to one or other of the said swivelling frames respectively, and which has one part attached to the said hinge means.

11. A nozzle according to claim **1,** wherein the fixed structure comprises a duct traversed by a gaseous flow and terminating in a downstream edge, and wherein said adjustable flaps can, under the action of the said control means, take up an open position in which their upstream edges come virtually into contact with the downstream edge of the duct, the flaps then forming a downstream extension of the duct, or a closed position in which their upstream edges are at a distance from the downstream edge of the duct, in such a way as to define a passage through which a flow of atmospheric air is able to penetrate said gaseous flow.

12. A nozzle according to claim **11,** wherein the flaps when forming a downstream extension of the duct are in alignment with the duct.

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